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AGGREGATE RESOURCES INVENTORY OF PUSLINCH TOWNSHIP Wellington County SOUTHERN ONTARIO

by
Staff of the Engineering and Terrain Geology Section
Ontario Geological Survey

1982

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Deputy Minister

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Every possible effort is made to insure the accuracy of the information contained in this report, but the Ministry of Natural Resources does not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

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ABSTRACT

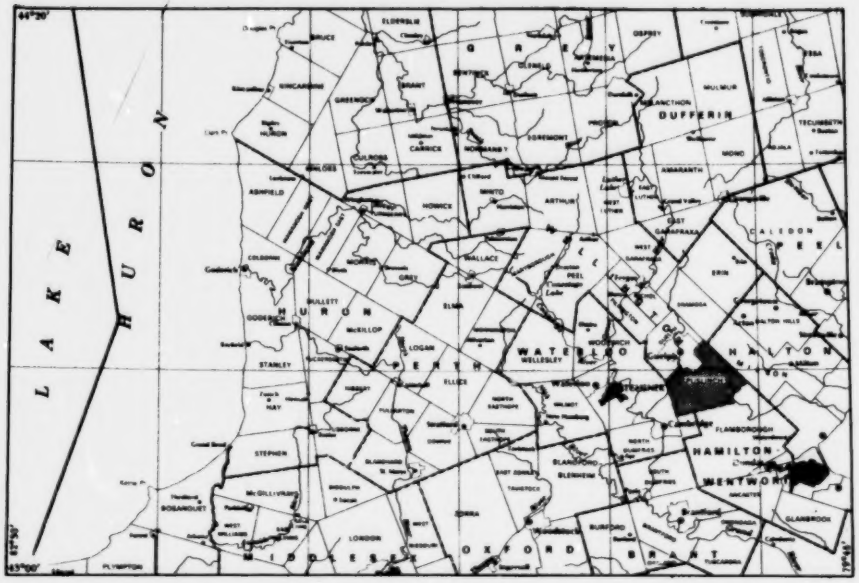


Figure 1 - Key Map Showing Location of Puslinch Township, Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in Puslinch Township. The report is part of the Aggregate Resources Inventory Program for townships designated under The Pits and Quarries Control Act, 1971.

In Puslinch Township, five areas containing significant amounts of sand and gravel have been selected for possible resource protection. Selected Sand and Gravel Resource Areas occupy 6200 acres (2500 ha), exclusive of licenced properties. An estimated 5400 acres (2180 ha) are currently available for extraction, containing possible resources of 320 million tons (290 million tonnes). The available portions of the Selected Areas make up 25 percent of the total area occupied by sand and gravel deposits in the township and 28 percent of the total resource tonnage.

Selected Sand and Gravel Resource Area 1 is an outwash deposit located near the hamlet of Aberfoyle. This deposit is the most important natural aggregate deposit in the township and contains an estimated 170 million tons (154 million tonnes) of sand and gravel. The aggregate is suitable for a range of road-building and construction products.

Selected Resource Areas 2 and 3 are outwash deposits located in the western part of the township. They contain available aggregate resources of 43 million tons (39 million tonnes) and 46 million tons (42 million tonnes), respectively. The aggregate is similar in quality to that in Area 1.

Selected Resource Areas 4 and 5 are outwash deposits located in the northwest part of the township. They contain available aggregate resources of 51 million tons (46 million tonnes) and 8 million tons (7 million tonnes), respectively. The aggregate in these Areas is suitable for a range of road-building and construction products.

Puslinch Township has large possible resources of sand and gravel, and is an important regional source of road-building and construction material. The Selected Areas contain significant resources and as much as possible of the existing material should be protected for possible future development.

Puslinch Township is underlain by bedrock of the Amabel Formation and Guelph Formation. Four areas have been selected for possible resource protection. These four Selected Areas are covered by less than 25 feet (8 m) of overburden. The Selected Areas cover 3250 acres (1320 ha) and contain possible resources of 570 million tons (520 million tonnes).

Stone from the Amabel Formation is acceptable for the production of high-quality crushed stone suitable for a variety of road-building and construction products, while the stone from the Guelph Formation is best suited for the production of lime and metallurgical stone.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF PUSLINCH TOWNSHIP[1]

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1979, the total tonnage of mineral aggregates extracted was 144 million tons (131 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1980).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

[1] Manuscript accepted for publication by Chief Engineering and Terrain Geology Section, Nov. 13, 1981. This paper is published with the permission of E.G. Pye, Director, Ontario Geological Survey.

PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). Wherever possible, field examination of potential resource areas was also undertaken to confirm interpretations made in the office. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-size fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Air photos at various scales were used to determine the continuity of deposits, especially in areas of limited subsurface information.

In the office, the pit data were supplemented by information on file with the Engineering Materials Office of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows: First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot thick layer of sand and gravel, one acre in extent, assuming an average density of 110 pounds per cubic foot.

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 represent only those parts of the deposit lying outside licenced areas (Column 2).

Two successive subtractions are made from the unlicenced area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas lying outside of licenced properties that have previously been extracted (e.g. wayside pits are included in this cateogry). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favourable bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of a workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot thick section of dolostone, one acre in extent, assuming a bulk density of 165 pounds per cubic foot).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot or approximately 3200 tons per acre. Shale resources are calculated on the basis of a bulk density estimate of 150 pounds per cubic foot.

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompny the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregates are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p. 7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

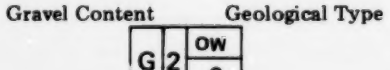
PART II - DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the distribution of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Map 1 is derived directly from the existing surficial geology maps of the area or from air photo interpretation where surficial mapping is incomplete. It shows the extent of sand and gravel deposits within the study area and serves as a base for the calculation of the total sand and gravel resources.

Map 1 presents a summary of all available information related to the quantity and quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbol which identifies each deposit. The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for a given deposit. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess fines may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identify the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identify the main quality limitations that may be present in the deposit as discussed in the next section.

The other information presented on Map 1 is designed to give an indication of the present level of extractive activity in the study area. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating under authority of a permit) are also identified and numbered on Map 1 and described in Table 2.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. These areas are identified on Map 2 by different shading patterns.

Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by a medium-grey tone on Map 2.

Selected Aggregate Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by a light grey tone on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the aggregate supply of the municipality.

Areas of tertiary significance are indicated on the map by a dashed line but have no grey tone. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extraction development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The "gravel content", (G or S), indicates the suitability of aggregate for various uses. Deposits containing more than 35 percent crushable gravel are considered to be favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Exesss "fines" or high silt and clay content may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fine content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent "oversize" particles (those greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building

aggregate, so must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is "lithology". Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C" "O" or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of those natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3.

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report but readers are encouraged to discuss them with personnel of the Ontario Ministry of Natural Resources' District Office.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain at roughly the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological

data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, bedrock topography, drift thickness maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources), and from geotechnical well data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the labelled bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three tones. The darkest tone indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance due to their easy access. The medium tone indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest tone indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and licenced acreage of the quarry and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and use of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of bedrock resource areas has been restricted to a single level of significance. Three factors support this approach. Quality and quantity variations are gradual. The areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material. Since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The wider range of possible resource areas allows greater flexibility in locating quarry operations away from areas of intensive land use competition. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such a resource area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN PUSLINCH TOWNSHIP

LOCATION AND POPULATION

Puslinch Township occupies an area of 57,101 acres (23 109 ha) in the southern part of Wellington County, southern Ontario. The Guelph (40 P/9) and Cambridge (40 P/8) map sheets of the National Topographic System, at a scale of 1:50 000, cover the area occupied by Puslinch Township.

Puslinch Township is flanked by the regional municipalities of Waterloo to the west, Halton to the east, and Hamilton-Wentworth to the south. Puslinch is a rural township, however the cities of Guelph and Cambridge lie within close proximity. Both of these centres have experienced substantial growth during the past ten years. The 1980 populations for Guelph and Cambridge were 73 165 and 75 716, respectively (Ontario Ministry of Intergovernmental Affairs 1981).

Puslinch Township, even though rural in nature, had a population of 4513 in 1980. Figures from the recent past indicate that the increase in population from 1973 to 1980 was moderate at 15 percent (Ontario Ministry of Intergovernmental Affairs 1981; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). The major segment of the municipality's residents are rural residential and estate residential. Estate-residential development increases the demands for mineral aggregates but also places a severe constraint on the extraction of mineral resources, often resulting in the sterilization of potential mineral aggregate resource areas.

Puslinch Township is traversed by King's Highways 401 and 6. Access within the township is also provided by a well developed grid of gravel-surfaced township roads and by paved county roads. The Canadian Pacific Railway has two lines through the township; one in the southern part running from Cambridge to Guelph Junction and Milton, and the other in the northern part running from Guelph to Guelph Junction. A third line belonging to the Canadian National Railway crosses the northwestern corner of the township.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography and distribution of surficial material in Puslinch Township, including the sand and gravel deposits shown on Map 1, are primarily the result of glacial activity that took place in the Late Wisconsinan Substage of the Pleistocene Epoch. This period of time, which lasted from approximately 23 000 to 10 000 years before present, was marked by the repeated advance and melting of extensive, continental ice sheets.

After the period of the maximum glacial extent part of central southern Ontario, including Puslinch Township, was covered by a submass of the main ice sheet known as the Lake Ontario lobe (Karrow 1968). The margin of the Ontario lobe advanced to the northwest over Puslinch Township and deposited a thick layer of glacial till over the bedrock surface and pre-existing sediments. This till is composed of sandy silt with minor stone content and is known as the Port Stanley Till. The till has little value as an aggregate source because of its high silt content.

Puslinch Township lies within three physiographic areas: the Guelph Drumlin Field; the Horseshoe Moraines; and the Flamborough Plain; (Chapman and Putnam 1966). The Guelph Drumlin Field, consisting of Port Stanley Till, occupies an area of 320 square miles (83 000 ha) (Chapman and Putnam 1966, p. 217) in the northwest portion of Puslinch Township.

Two major moraines make up the Horseshoe Moraines physiographic region in this area. Together, the Paris and Galt moraines form a belt 4 to 5 miles (6 to 8 km) wide (Karrow 1968, p. 10). The Paris Moraine was formed by the margin of the Ontario ice-lobe as it retreated into the Lake Ontario basin and the Galt Moraine was deposited during a readvance of the margin during its retreat. The Paris and Galt moraines are both composed of sandy Wentworth Till, and extend through Puslinch Township from north to southwest, with the Paris Moraine situated north and west of the Galt Moraine.

The Flamborough Plain, located in the southeast section of the area, is an isolated tract of shallow drift that consists of bouldery glacial till or sand and gravel (Chapman and Putnam 1966). The Flamborough Plain constitutes an area of about 150 square miles (39 000 ha), and in places the limestone has been washed bare by

lacustrine wave action.

Related to the Paris and Galt moraines is an integrated system of spillways with broad gravel and sand terraces (Chapman and Putnam 1966). The best sources of sand and gravel for the aggregate industry come from these sand and gravel terraces. Excellent cross-sections of the Horseshoe Moraines area can be seen along King's Highway 6 south from Guelph to Puslinch, or along King's Highway 401 (Chapman and Putnam 1966). Portions of the Horseshoe Moraines area are very hilly with a local relief of more than 100 feet (30 m) (Chapman and Putnam 1966, p. 200). Kettles and kettle lakes (e.g. Puslinch Lake) are also prominent.

An extensive outwash plain between Killean Station and Aberfoyle separates the Galt and Paris moraines. This outwash plain was apparently fed by glacial meltwaters when the ice stood at the Galt Moraine. Coarser aggregate deposits of the spillway channel are concentrated southwest of Aberfoyle where the material is now extracted in the T.C.G. Materials Limited pit (Deike 1978). To the north of the Paris Moraine are gravel terraces of the Speed and Eramosa Rivers. Numerous extractive operations exist in this area.

The aforementioned deposits are the main economic deposits in Puslinch Township, however several small operations are found in the kame, esker and beach gravels southeast of the Galt Moraine.

After its brief halt at the Galt Moraine, the margin of the Ontario lobe retreated from Puslinch Township, thus marking the end of glacial activity in the area. Postglacial erosional and depositional processes have since been of minor importance in modifying the physiography of the township and the land still shows the strong influence of the glacial ice.

EXTRACTIVE ACTIVITY

Many sand and gravel pits have been opened in outwash, esker and ice-contact stratified drift deposits scattered throughout Puslinch Township.

At the writing of this report, records on file at the Cambridge District Office of the Ontario Ministry of Natural Resources indicated that 15 properties were licenced for extraction, consisting of 13 pits and 1 quarry and one property licenced as both a pit and quarry operation. The total area licenced is 1660.5 acres (672.0 ha). The average amount of material extracted annually from licenced pits and quarries between 1976 and 1979 was 1.9 million tons (1.7 million tonnes).

Materials extracted from pits and quarries in Puslinch Township reach two types of market destinations: major urban centres from which the major demand exists for Puslinch Township aggregates; and local township road projects. Puslinch Township aggregate operations export 50 percent of their total production to Toronto, Hamilton, Cambridge and Guelph (Proctor and Redfern 1974).

SELECTED SAND AND GRAVEL RESOURCES

Puslinch Township has a considerable acreage underlain by sand and gravel (Map 1). The total area occupied by these deposits is 21,200 acres (8600 ha), containing resources of approximately 1150 million tons (1040 million tonnes) of aggregate. Much of this material, however, has little crushable gravel and limited potential for use as road-building or construction aggregate.

The sand and gravel deposits selected for possible resource protection in Puslinch Township are shown on Map 2. Five large outwash deposits in the township have been selected as Sand and Gravel Resource Areas of Primary Significance. The portions of the Selected Sand and Gravel Resource Areas of Primary Significance which are available for extraction have total resources of 320 million tons (290 million tonnes). The Selected Resource Areas occupy 25 percent of the total area of sand and gravel deposits in Puslinch Township, and represent 28 percent of the township's total resource tonnage. The Selected Areas contain most of the township's possible resources of crushable aggregate.

In addition, three outwash deposits have been selected as resource areas at the secondary level. Although these areas are not the "best" deposits in the township, they contain aggregate which may be useful at a local scale. Consequently they should be considered as an integral part of the township's resource base.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is an outwash deposit associated with the Galt Moraine. This deposit is situated near the junction of King's Highways 401 and 6 and occupies a total of 3550 acres (1440 ha), of which 1000 acres (400 ha) are licenced. The six licenced operations in this deposit (pit nos. 4, 5, 6, 7, 8 and 14) are normally working a 20- to 30-foot (6 to 9 m) face above the water table, and on several properties an additional 20 feet (6 m) of material below the water table are removed by dragline. This deposit is well stratified and sorted in most exposures and there is generally less than 5 percent oversize material. Removing previously extracted areas and cultural setbacks, the available resource area consists of approximately 2260 acres (920 ha). The Galt-Aberfoyle Creek drainage system bisects the deposit, and results in portions of the deposit being covered by wetland.

Selected Sand and Gravel Resource Area 1 has a great thickness of usable material. Portions of the deposit have depths of up to 60 feet (18 m), with 40 to 70 percent gravel content. Because the material in the eastern side of the Area was deposited close to the ice front, the sand and gravel are less well sorted, but thicker, than in the western part. The material also becomes finer towards the west. Data for the deposit, from the Ontario Ministry of Transportation and Communications (M.T.C.), indicate that the aggregate materials are acceptable for concrete and hot-mix applications as well as for road base uses. Road sub-base products such as Granular Base Course (G.B.C.) A, B and C can be produced (Deike 1976). The M.T.C. suggests that the sand grades dirty for Hot-Laid No. 4 applications, and coarse and dirty for hot-laid asphaltic mixes. The material therefore requires blending for hot-mix applications.

Assuming an average thickness of 30 feet (9 m) throughout the whole deposit, the presently available sand and gravel resources in Area 1 are estimated to total 170 million tons (154 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 is composed of outwash material and is part of the outwash terrace of the Speed River.

The Resource Area occupies a total of 760 acres (310 ha), of which 690 acres (280 ha) are presently available for extraction. The licenced area (approximately 185 acres (75 ha)) is composed of three properties (pit nos. 11, 12 and 13). These properties have face heights of approximately 15 to 20 feet (5 to 6 m). Portions of the deposit have considerably greater thickness. The gravel content is approximately 70 percent in the licenced properties; however, over the whole deposit the gravel content will average 60 percent.

Road sub-base products such as Granular Base Course A and C can be produced (Deike 1976). Blending of different sand grades is also required in some areas to produce acceptable hot-laid aggregates.

Assuming an average thickness of usable material of 25 feet (8 m), the presently available resources total 43 million tons (39 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Resource Area 3 is part of the outwash plain and spillway deposit associated with the Paris Moraine. The Area is located north of Puslinch Lake and southwest of the City of Guelph and comprises 1200 acres (485 ha) with an average depth of material of 20 feet (6 m).

There are no licenced pits in this area. Several abandoned or rehabiliated pits do exist and wayside permits have been issued for extraction from one property. The area contains a large quantity of crushable gravel of high quality. Gravel content is approximately 60 percent in the deposit. The water table is high throughout much of this area, located generally 10 to 15 feet (3 to 5 m) below the surface. Laboratory tests performed by the Ministry of Transportation and Communications on the materials from the Puslinch Crown Resources Management Area indicate that the gravel is suitable for G.B.C. A and 5/8 inch (16 mm) crushed stone types A and B. The stone portion is of acceptable quality for Hot-Laid No. 3, 4, 5, 6 and 8 and for structural and paving-course aggregates. The sand portion meets the specifications for all grades of hot-laid asphalt as well as concrete sand. Since there is a high percentage of silt, blending will be necessary for all hot-laid uses (Deike 1978;

Katona 1974). Although the above data pertains to the Puslinch Crown Resource Management Area, the material in the remainder of the Selected Area will be similar in nature.

After considering cultural constraints, the available area of Area 3 is 930 acres (375 ha). Assuming an average depth of material of 20 feet (6 m), the possible resources are 46 million tons (42 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 4

Selected Sand and Gravel Resource Area 4 consists of an outwash deposit in the northwestern part of the township. A study was conducted by Dominion Soil Investigation Inc. (1979) in the northern part of the deposit. The examination revealed that the deposit is generally coarser near the surface and becomes finer with depth. Average thickness is 15 feet (5 m) but underlying the coarse aggregate an additional 23 feet (7 m) (average) contain fine material marginally suitable for granular use. The upper portion appears suitable for Granular B and C with some portions suitable for crushing into Granular A. With processing some parts of the deposit would be suitable for concrete and asphalt sand.

Resource Area 4 occupies 1550 acres (630 ha), of which 1360 acres (550 ha) are presently available for extraction. Assuming an average thickness of usable material of 15 feet (5 m), the presently available resources total 51 million tons (46 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 5

Selected Sand and Gravel Resource Area 5 occupies an area of approximately 130 acres (53 ha) on the north side of the Speed River. A large part of the deposit lying within Puslinch Township is licenced to Standard Aggregates (pit no. 10) as both a pit and a quarry.

This deposit is part of the Speed River outwash terraces and is considered to have a 30-foot (9 m) depth with a gravel content of 35 to 60 percent. After subtracting cultural setbacks, 110 acres (44 ha) outside of the licenced area are available for extraction, containing estimated resources of 8 million tons (7 million tonnes).

Road sub-base products such as Granular Base Course A, B and C can be produced. The gravels are also suitable for 5/8 inch (16 mm) crushed stone, hot-laid asphalt and concrete uses, provided that suitable processing is carried out.

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

Three outwash deposits have been selected as Sand and Gravel Resource Areas of Secondary Significance. Although these deposits are not the "best" resources they should be considered an integral component of the township's aggregate supply.

The first of the outwash deposits is considerably thick and extensive and is located south of the Eramosa River, in the northeastern part of Puslinch Township. Data from water well records and from licenced sand and gravel pits indicate that the deposit is predominantly gravel with a thickness of 20 to 55 feet (6 to 17 m). One licenced sand and gravel pit has been opened in this Secondary Resource Area (pit no. 2). A 20-foot (6 m) face at pit no. 2 exposes poorly sorted, often coarse aggregate consisting of approximately 60 percent gravel and 40 percent sand. This deposit is relatively undeveloped but does contain large aggregate reserves (Burwasser 1976). The deposit continues through the southern part of Guelph, where the quality of the material improves, and becomes part of Selected Area 4. However, field investigation reveals that the aggregate in this part of the outwash deposit is much poorer in quality than that in Resource Area 4, and has thus been selected at the secondary level.

The second outwash deposit of secondary significance is an outwash plain located along the west side of the Paris Moraine. This deposit is located directly northeast of Selected Sand and Gravel Resource Area 3. Water well information suggests a possible depth of 70 feet (21 m) of gravel, however quality data are scarce for the deposit.

The remaining Secondary Sand and Gravel Resource Area is an outwash terrace found in channels that are associated with the Eramosa River complex. This Secondary Area is located on the northeastern boundary of the township. No subsurface data are available for this deposit

and there has been no extractive activity. A property to the north of the township in the same deposit reveals a 15-foot (5 m) face with a gravel content of 50 to 60 percent. This outwash terrace has been designated as secondary because it contains insufficient reserves for large-scale commercial production resulting from the large acreage lost to cultural setbacks.

BEDROCK GEOLOGY

Bedrock underlying Puslinch Township consists of Silurian dolostone of the Amabel Formation and Guelph Formation. The bedrock surface is relatively flat and dips gently southwest at 20 to 30 feet per mile (4 to 6 m per km) (Morrison and Beatty 1979). The distribution of these units is shown on Map 3 (after Telford 1976; 1979). Drift cover over the bedrock surface ranges from none at outcrop exposures to more than 100 feet (30 m).

The Amabel is the older of the two formations. This formation occurs in the southeast part of Puslinch Township under 3 to 50 feet (1 to 15 m) of drift cover. The formation has been separated into two units in this area on the basis of persistent textural differences. The upper portion of the formation is named the Eramosa Member, and consists of very thin-to medium-bedded, fine-crystalline bituminous dolostone with some sandy layers (Telford 1976; 1979). The thickness of the Eramosa Member in this area ranges from approximately 50 to 80 feet (15 to 25 m) (Telford 1979). This member is not always suitable for the production of load-bearing crushed aggregate; one area has been selected for possible protection, however poor stone quality in the northern part of the township prevents the Eramosa from being selected for protection in this area. The remainder of the Amabel Formation consists of white microcrystalline to fine-crystalline fossiliferous dolostone. The formation is approximately 100 to 115 feet (30 to 35 m) thick (Telford 1979). The formation is well suited for the production of high-quality construction and road aggregates and is a resource of provincial significance for these uses. One area of the Amabel Formation, covered by thin drift, has been selected for possible resource protection.

The Amabel Formation is overlain to the north and west by the Guelph Formation which subcrops in the remainder of Puslinch Township. The Guelph Formation is a buff-coloured fine-grained dolostone usually of high purity (Telford 1976; 1979). This formation is also characterized by reefy facies. It is not usually acceptable for the production of crushed stone aggregate because of its low resistance to breaking and wear. However, stone from the Guelph Formation is a valuable raw material for numerous metallurgical products (Hewitt 1960). Guelph Formation dolostone is mined for the manufacture of dolomitic lime used in the production of quicklime and high-quality white hydrated lime.

In Puslinch Township there are two properties licenced for quarrying. One property is licenced to Domtar Inc., Domtar Chemicals Group, and is situated at Lots 1-3, Concession 4, comprising 195.0 acres (78.9 ha). The other property is operated by Standard Industries and is situated at Lots 7-11, Concession 5, comprising 148.4 acres (60.0 ha). This property is licenced both as a gravel pit and as a quarry, however, active quarrying of bedrock has not yet occurred on the property. The bedrock underlying this property is the Guelph Formation. The stone from both quarries is best suited for use in the manufacture of lime and metallurgical stone.

SELECTED BEDROCK RESOURCE AREAS

SELECTED BEDROCK RESOURCE AREAS 1a AND 1b

Selected Bedrock Resource Areas la and lb are both underlain by the Guelph Formation. The Areas are located in the Puslinch-Crieff area, and are covered by less than 25 feet (8 m) of overburden (Map 3). Selected Areas la and lb are separated by a geological thickness boundary (Map 3) that is primarily based on the thickness of the Guelph Formation in the Puslinch-Crieff area. The boundary marks the approximate point where the Guelph Formation reaches 30 feet (9 m) in thickness. Estimated workable thickness in Selected Area lb east of the boundary includes 30 feet (9 m) of the Eramosa Member which underlies the Guelph Formation. Resource Areas la and lb total 1570 acres (640 ha), of which 1200 acres (485 ha) are available for quarrying. Of this, 590 acres (240 ha) have bedrock outcropping at or near the surface. Both Resource Area 1a and 1b extend into the Township of Flamborough for a considerable distance. Assuming a total workable thickness of

60 feet (18 m), the bedrock reserves presently available for extraction in both Resource Areas are estimated to be 260 million tons (235 million tonnes).

There are no operating quarries in either Resource Area at the present time. However, there is one abandoned quarry (quarry no. 3) in Resource Area 1a, and another (quarry no. 4) in Resource Area 1b. The Areas are traversed by a line of the Canadian Pacific Railway and by numerous gravel-surfaced roads.

SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2 is underlain by the Guelph Formation dolostone. This Selected Area is located between Guelph and Cambridge straddling the Speed River, and is covered by less than 25 feet (8 m) of overburden (Map 3). The Resource Area consists of 1080 acres (435 ha), of which 910 acres (370 ha) are available for extraction. Assuming a total workable thickness of 60 feet (18 m) in this part of the formation, the bedrock resources presently available for extraction are estimated to be 197 million tons (179 million tonnes). There are two licenced quarries in this area (quarry nos. 1 and 2). Domtar Chemicals Lime Division has an operating quarry at Lots 1, 2 and 3, Concession 4. This property has been in operation for many years, dating back to before the turn of the century. The quarry has produced dolomitic lime, hydrated lime and limestone. Standard Industries Limited also has a licenced quarry in this area, situated two miles to the north of the Domtar Chemicals Limited operation. This property is also licenced as a sand and gravel pit and presently it is only being mined above the bedrock in the unconsolidated sands and gravels.

Bedrock Resource Area 2 is very well situated with respect to road and rail transportation routes.

SELECTED BEDROCK RESOURCE AREA 3

Selected Bedrock Resource Area 3 is underlain by the Amabel Formation and is covered by less than 25 feet (8 m) of overburden (Map 3). This Area is located in the vicinity of Mountsberg and extends both north and south of King's Highway 401. The Resource Area consists of 375 acres (152 ha), of which 335 acres (136 ha) are available for extraction. Assuming a total working thickness of 60 feet (18 m) in this part of the formation, the crushed stone resources presently available for extraction are estimated to be 72 million tons (65 million tonnes). Stone from the Amabel Formation is suitable for a wide range of road-building products as well as high-specification concrete and asphalt aggregate. Bedrock Resource Area 3 is traversed by King's Highway 401 and by gravel-surfaced roads.

SELECTED BEDROCK RESOURCE AREA 4

Selected Bedrock Resource Area 4 is underlain by the Eramosa Member of the Amabel Formation. The Area consists of two parts of the Eramosa where drift thickness is less than 25 feet (8 m). The Area is located near the hamlet of Puslinch (Map 3). The Resource Area consists of 245 acres (99 ha), of which 210 acres (85 ha) are available for extraction. Assuming a total working thickness of 50 feet (15 m), the crushed stone resources presently available for extraction are estimated to be 38 million tons (34 million tonnes). There are presently no quarries in this Area, however the Eramosa dolostone in this part of the township is acceptable for the production of high-quality aggregate. Bedrock Resource Area 4 is well situated with respect to road and rail transportation. The Resource Area is traversed by gravel-surfaced roads and a line of the Canadian Pacific Railway.

SUMMARY

Puslinch Township has significant possible resources of sand and gravel and should be able to meet local requirements for many years. Five areas of primary significance have been selected for possible resource protection. The Selected Resource Areas contain approximately 320 million tons (290 million tonnes) of good-quality crushable gravel and constitute a regionally significant resource. Additional resources may by available in other outwash deposits which have been selected as Sand and Gravel Resource Areas of Secondary Significance. Care should be taken to ensure the continuing availability of as much of the Resource Areas as possible.

Possible bedrock resources in Puslinch Township belong to the Amabel and Guelph Formations. Stone from the Amabel Formation is acceptable for the production of crushed stone that is suitable for a range of road-building and construction products, while stone from the Guelph Formation is suitable for the production of chemical lime and metallurgical lime. Four Resource Areas have been selected for possible protection, containing total resources of approximately 570 million tons (520 million tonnes).

Enquiries regarding the Aggregate Resources Inventory of Puslinch Township should be directed to the Ontario Ministry of Natural Resources either at the Cambridge District Office, Beaverdale Road, Box 2186, Cambridge, Ontario, N3C 2W1 (Tel. (519) 658-9356), or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (Tel. (416) 884-9203).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, PUSLINCH TOWNSHIP

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
1	G-E	50 (20)	2 (2)
	G-IC	2650 (1070)	180 (163)
	G-K	20 (8)	1 (1)
	G-OW	9800 (3950)	750 (680)
2	G-E	120 (49)	4 (4)
	G-IC	1760 (710)	70 (64)
	G-OW	1250 (510)	59 (54)
	S-OW	30 (12)	1 (1)
3	G-IC	1200 (490)	30 (27)
	G-OW	325 (132)	8 (7)
4	G-E	75 (30)	1 (1)
	G-IC	875 (355)	11 (10)
	S-IC	340 (138)	4 (4)
	G-K	25 (10)	<1 (<1)
	S-K	40 (16)	<1 (<1)
	S-LP	300 (121)	4 (4)

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, PUSLINCH TOWNSHIP

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
	G-OW	930 (375)	12 (11)
	S-OW	1360 (550)	17 (15)
		21,200 (8600)	1150 (1040)

N.B. Minor variations in above table are due to rounding of data.

TABLE 2 | SAND AND GRAVEL PITS, PUSLINCH TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
1		Fred E. Prior & Sons Ltd.	1	9	16.2 (6.6)	30 (9)	50
2		Preston Sand & Gravel Co. Ltd.	3-6	9	90.0 (36.4)	20 (6)	60
3	G1-288	Twp. of Puslinch (A. McLean)	26	10	7.1 (2.9)	10 (3)	50
4	G1-85	Custom Aggregate	23, 24	7	181.5 (73.4)	25 (8)	40-60
5	G1-172	TCG Materials Ltd.	24, 25 26, 27	7 6	306.0 (123.8)	25 (8)	60-70
6		TCG Materials Ltd.	23	7	80.0 (32.4)	15 (5) plus 20 feet (6 m) below water table	10-35
7	G1-186	Capital Paving Ltd.	22	7	100.0 (40.5)	15-20 (5-6)	50-60
8	G1-115	S. McNally & Sons Ltd.	25, 26	2	139.0 (56.2)	20 (6)	70-75
9		Gordonville Developments	31	Gore	17.5 (7.1)	20 (6)	50-75
10*		Standard Industries	7-11	5	148.4 (60.1)	20 (6)	35-60
11		Cox Construction Ltd.	5	4	80.2 (32.5)	15-20 (5-6)	60-70
12		Preston Sand & Gravel Co. Ltd.	4	4	88.0 (35.6)	20 (6)	60-70
13	G1-251	Henry A. Holman	3	4	15.6 (6.3)	20 (6)	65-80
14		Custom Aggregate	22, 23	9	196.0 (79.3)	–	–
					1465.5 (593.1)		

TABLE 2 | SAND AND GRAVEL PITS, PUSLINCH TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
UNLICENCED PITS**							
15	G9-98	S.W. Adams	9, 10	8		10 (3)	75-85
16	G1-66	K.R. Fair	13	7		10 (3)	55-70
17	G7-14	Ord	20	7		10-20 (3-6)	0-25
18	G1-18	Gilmour	24	8		10-20 (3-6)	35-40
19	G1-15	A. Chopka (C. Mischuk)	21	8		rehabilitated	
20	G1-19	Armour (Billing's)	20	8		10-20 (3-6)	35-40
21	G1-191	Clark's Pit	29	9		10-20 (3-6)	40-60
22	G1-189	Scott's Pit # 2 (Campbell)	34	9		4-15 (1-5)	9-60
23	G1-107	Kerr	26	7		15 (5)	75(5)
24	G1-36	McNaughton	33	Gore		8 (2)	30-35 partially depleted
25	G1-21	Curry	35	Gore		15-30 (5-9)	15-70 partially depleted
26	G1-262	Patterson # 1	35	Gore		15 (5)	5-80 partially depleted
27	G1-263	Patterson # 2	36	Gore		10 (3)	12-60 partially depleted
28	G1-16	Gallo	30	Gore		20-35 (6-11)	50-80

TABLE 2 | SAND AND GRAVEL PITS, PUSLINCH TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
29	G1-83	Guy	13	1		30-40 (9-12)	60
30	G1-173	MNR	6, 7	2		7-15 (2-5)	60-70
31	G1-175	Gamble	7	2		9 (3)	70 rehabilitated
32	G1-100	Baardzilauskes	14	2		30 (9)	60-75
33	G1-99	Love	9	4		55 (17)	50-85

* This property is licenced for both pit and quarry operations.
** Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, PUSLINCH TOWNSHIP

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
1	2550 (1030)	285 (115)	5 (2)	2260 (920)	30 (9)	170 (154)
2	760 (310)	70 (28)	0 (0)	690 (280)	25 (8)	43 (39)
3	1200 (485)	235 (95)	35 (14)	930 (375)	20 (6)	46 (42)
4	1550 (630)	185 (75)	5 (2)	1360 (550)	15 (5)	51 (46)
5	130 (53)	20 (8)	0 (0)	110 (44)	30 (9)	8 (7)
	6200 (2500)	800 (325)	45 (18)	5400 (2180)		320 (290)

N.B. Minor variations in above table are due to rounding of data.

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, PUSLINCH TOWNSHIP

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
0-3 (0-1)	Guelph	60 (18)	590 (240)	127 (115)
3-25 (1-8)	Guelph	60 (18)	2460 (1000)	530 (480)
25-50 (8-15)	Guelph	60 (18)	2320 (940)	500 (455)
			5400 (2180)	1160 (1050)
0-3 (0-1)	Amabel (Eramosa Member)	50 (15)	40 (16)	7 (6)
3-25 (1-8)	Amabel (Eramosa Member)	50 (15)	1740 (700)	315 (285)
25-50 (8-15)	Amabel (Eramosa Member)	50 (15)	3750 (1520)	680 (620)
			5500 (2230)	1000 (910)
3-25 (1-8)	Amabel	60 (18)	390 (158)	84 (76)
25-50 (8-15)	Amabel	60 (18)	310 (126)	67 (61)
			700 (285)	151 (137)
			11,600 (4700)	2,300 (2100)

N.B. Minor variations in above table are due to rounding of data.

TABLE 5 | QUARRIES, PUSLINCH TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
LICENCED QUARRIES						
Q1		Domtar Inc.	1, 2, 3	4	195.0 (78.9)	60 (18)
Q2		Standard Industries Ltd.	7-11	5	148.4 (60.0)	nil
					343.4 (139.0)	
UNLICENCED QUARRIES*						
Q3		Gypsum, Lime and Alabastine Can. Ltd.	29	Gore		9 (3) above ground-water
Q4		Steetley Industries	35	Gore		18 (6) above ground-water
						10-25 (3-8) below ground-water

*Abandoned quarries or wayside quarries operating on demand under authority of a permit.

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, PUSLINCH TOWNSHIP

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
1a	0-25 (0-8)	600 (243)	110 (44)	5 (2)	485 (196)	60 (18)	105 (95)
1b	0-25 (0-8)	970 (395)	240 (97)	10 (4)	720 (290)	60* (18)	156 (142)
2	3-25 (1-8)	1080 (435)	170 (69)	0 (0)	910 (370)	60 (18)	197 (179)
3	3-25 (1-8)	375 (152)	40 (16)	0 (0)	335 (136)	60 (18)	72 (65)
4	3-25 (1-8)	245 (99)	35 (14)	0 (0)	210 (85)	50 (15)	38 (34)
		3250 (1320)	600 (245)	15 (6)	2650 (1070)		570 (520)

N.B. Minor variations in above table are due to rounding of data.

*Estimated workable thickness in this Selected Area includes 30 feet (9 m) of the Eramosa Member which underlies the Guelph Formation.

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APPENDIX B - GLOSSARY

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

CAMBRIAN

The first Period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

CLAST

An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a large rock mass. Synonyms include particle and fragment.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone, and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN

A Period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DIRT

See fines.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.074 mm). Also described informally as "dirt", these particles are in the silt- and clay-size range.

GLACIAL LOBE

A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GRADATION

The proportion of material of each particle size or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder		>-256 mm
Gravel	cobble	64-256 mm
Gravel	pebble	4-64 mm
Gravel	granule	2-4 mm
Sand	coarse	.5-2 mm
	medium	.25-.5 mm
	fine	.074-.25 mm
Silt, clay		<.074 mm

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability, and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

H.L. (HOT-LAID OR ASPHALTIC AGGREGATE)

Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3, and 4), or as binder course (H.L. 2, 6, and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition, and grain size. Generally, the description of the physical character of a rock.

MELTWATER CHANNEL

A drainage way, usually terraced, produced by water flowing away from a melting glacier margin.

ORDOVICIAN

An early peiod of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA

One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago. The Paleozoic Era (or Ancient Life Era) is subdivided into six geologic Periods, of which only four (Cambrian, Ordovician, Silurian, and Devonian) can be recognized in southern Ontario.

PLEISTOCENE

An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity.

POSSIBLE RESOURCE

Estimates of mineral aggregate material based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples of measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt, or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone, and mudstone.

SILURIAN

An early Period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial stage of the Pleistocene Epoch in North America. It began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Winsconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 7000 to 85 000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and they can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain-size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good-quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the presence of excess fines (silt- and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. They vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout southern Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain-size variability. They are given a qualita-

tive rating based on existing pit and other subsurface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. They occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain-size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amount of crushable aggregate in alluvial deposits in low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAIN (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. They commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

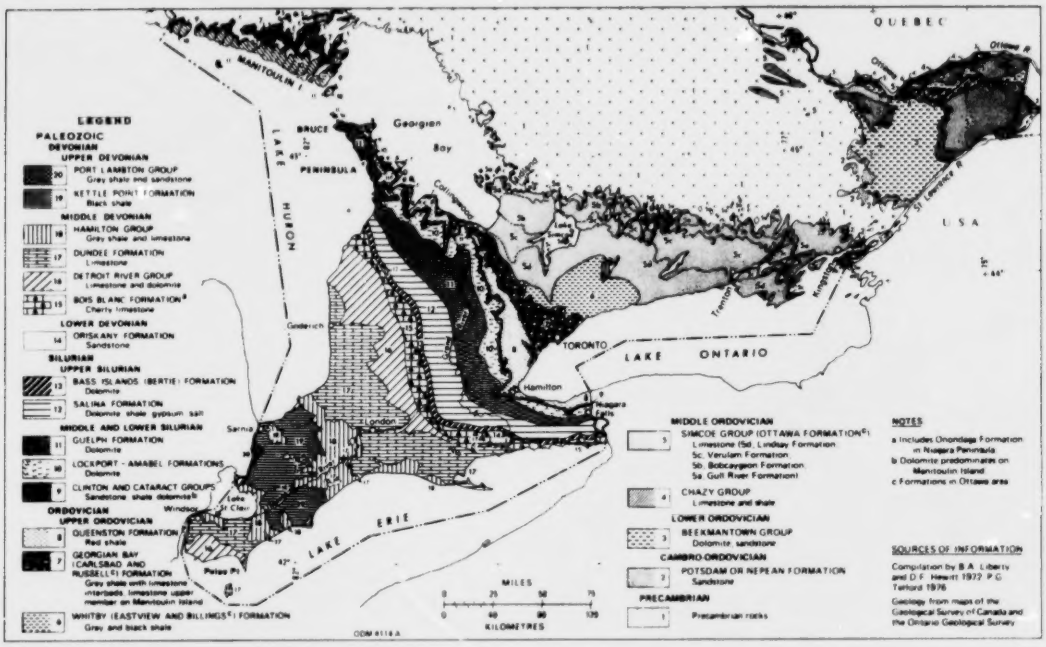
EOLIAN DEPOSITS

WINDBLOWN FORMS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from,

and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments are almost invariably composed of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS



BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

BASS ISLANDS FORMATION (UPPER SILURIAN)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11-18m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate due to high soundness losses.

BOBCAYGEON FORMATION (MIDDLE ORDOVICIAN)

Composition: Compact, homogeneous, medium- to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

BOIS BLANC FORMATION (LOWER-MIDDLE DEVONIAN)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion

Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

DUNDEE FORMATION (MIDDLE DEVONIAN)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

GULL RIVER FORMATION (MIDDLE ORDOVICIAN)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County, and Uthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

LOCKPORT AND AMABEL FORMATIONS (MIDDLE SILURIAN)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Watertown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, and building stone throughout their area of occurrence, and are a valuable aggregate resource. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

ONONDAGA FORMATION (MIDDLE DEVONIAN)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliffe Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey brown, fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

OTTAWA FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Falls Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

OXFORD FORMATION (LOWER ORDOVICIAN)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES.

DETROIT RIVER GROUP (MIDDLE DEVONIAN)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change). Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important

source of high purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces 80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas formation is quarried at Amherstburg for crushed stone.

GRENVILLE MARBLE (PRECAMBRIAN)

Composition: Recrystallized white limestone and dolostone, fine- to coarse-grained, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazo chips, poultry grit, decorative stone, and building stone.

GUELPH FORMATION (MIDDLE SILURIAN)

Composition: Aphanitic- to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. It is quarried at Glen Christie and Guelph.

LINDSAY FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Member: fine-crystalline, rubbly, nodular, weathering limestone. Upper Member: grey calcareous claystone with shaly partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point, Colborne, and Bowmanville for lime. It is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

VERULAM FORMATION (MIDDLE ORDOVICIAN)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200-300 feet (61-91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for lime. It is unsuitable for crushed stone due to clay impurities and many clayey interbeds, low abrasion resistance. High soundness losses and poor freeze-thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

GEORGIAN BAY FORMATION (UPPER ORDOVICIAN)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas). Composition: Soft, fissile, blue grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Five producers in Metro Toronto and Cooksville produce brick and structural tile (Guillet 1967). Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

HAMILTON GROUP (MIDDLE DEVONIAN)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The Group has six formations. Only the Arkona is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

QUEENSTON FORMATION (UPPER ORDOVICIAN)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are 12 large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa (Guillet 1967). All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

NEPEAN (POTSDAM) FORMATION (CAMBRO-ORDOVICIAN)

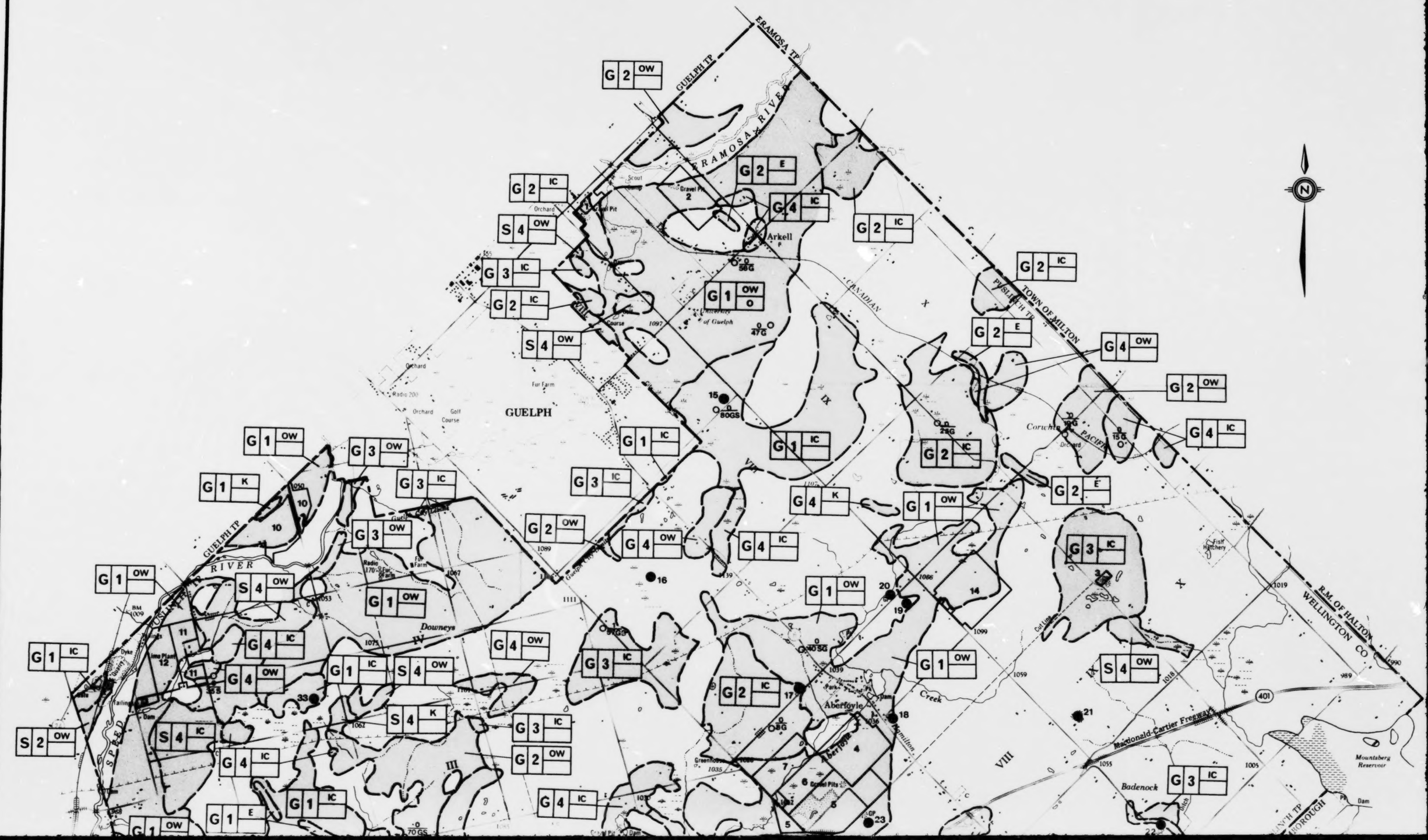
Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

SALINA FORMATION (UPPER SILURIAN)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

WHITBY FORMATION (UPPER ORDOVICIAN)

(Formerly known as Collingwood Shale near Toronto). Composition: Brown to black fissile shale. Uses: Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggregate.


ERAMOSA TP.
GUELPH TP.
ERAMOSA RIVER
G 2 OW
G 2 IC
G 2 E
G 4 IC
G 2 IC
S 4 OW
G 3 IC
G 2 IC
G 1 OW O
S 4 OW
G 2 IC
G 4 OW
G 2 E
G 2 OW
G 4 IC
G 1 IC
G 1 IC
G 3 IC
G 1 K
G 3 OW
G 3 IC
G 3 OW
G 2 OW
G 4 OW
G 4 IC
G 4 K
G 1 OW
G 2 E
G 3 IC
G 1 OW
S 4 OW
G 1 OW
G 1 IC
G 4 IC
G 4 OW
G 1 IC
S 4 OW
G 4 OW
S 4 K
S 2 OW
S 4 IC
G 4 IC
G 3 IC
G 2 OW
G 1 IC
G 1 E
G 1 OW
G 4 IC
G 1 OW
G 3 IC
G 2 IC
G 1 OW
S 4 OW
G 2 IC
G 3 IC
GUELPH
Arkell
Aberfoyle
Downeys
Badenock
Corwhin
Scout Camp
Gravel Pit 2
Orchard
Golf Course
Radio 200
Fur Farm
Radio 170 - Fur Farm
Dyke
Dump
Sewage Lagoons
Sewage Treatment Plant
Tailings
Dam
Creek
Aberfoyle Pond
Gravel Pits
Greenhouses
Fish Hatchery
Mountsberg Reservoir
Macdonald-Cartier Freeway
401
CANADIAN PACIFIC
TOWN OF MILTON
PUSLINCH TP.
R.M. OF HALTON
WELLINGTON CO.
GUELPH TP.
PUSLINCH TP.
SPEED
Hamilton
University of Guelph
Gravel Pit
Ditch
Pit
Pipeline
Transmission Line
Power Line
Railway
Road
Trail
Bridge
Culvert
Swamp
Marsh
Orchard
Cultivated
Pasture
Woodland
Contour
Spot Elevation
Bench Mark
Triangulation Station
Church
Cemetery
Building
Well
Windmill
Quarry
Gravel Pit
Sand Pit
Clay Pit
Shale Pit
Peat Bog
Sand
Gravel
Clay
Shale
Peat
Bedrock
Boulders
Stoniness
Drainage
Erosion
Flooding
Topography
Soil Boundary
Soil Name
Soil Type
Soil Phase
Soil Complex
Soil Association
Soil Group
Soil Series
Soil Map Unit
Soil Survey
Soil Profile
Soil Horizon
Soil Texture
Soil Structure
Soil Color
Soil Reaction
Soil Moisture
Soil Temperature
Soil Fertility
Soil Organic Matter
Soil Nitrogen
Soil Phosphorus
Soil Potassium
Soil Calcium
Soil Magnesium
Soil Sulfur
Soil Micronutrients
Soil Boron
Soil Copper
Soil Iron
Soil Manganese
Soil Molybdenum
Soil Zinc
Soil Chlorine
Soil Cobalt
Soil Sodium
Soil Aluminum
Soil Silicon
Soil Vanadium
Soil Selenium
Soil Fluorine
Soil Iodine
Soil Arsenic
Soil Lead
Soil Mercury
Soil Cadmium
Soil Chromium
Soil Nickel
Soil Tin
Soil Barium
Soil Strontium
Soil Titanium
Soil Zirconium
Soil Lithium
Soil Rubidium
Soil Cesium
Soil Gallium
Soil Germanium
Soil Scandium
Soil Yttrium
Soil Lanthanum
Soil Cerium
Soil Praseodymium
Soil Neodymium
Soil Samarium
Soil Europium
Soil Gadolinium
Soil Terbium
Soil Dysprosium
Soil Holmium
Soil Erbium
Soil Thulium
Soil Ytterbium
Soil Lutetium
Soil Hafnium
Soil Tantalum
Soil Tungsten
Soil Rhenium
Soil Osmium
Soil Iridium
Soil Platinum
Soil Gold
Soil Mercury
Soil Thallium
Soil Lead
Soil Bismuth
Soil Polonium
Soil Astatine
Soil Radon
Soil Francium
Soil Radium
Soil Actinium
Soil Thorium
Soil Protactinium
Soil Uranium
Soil Neptunium
Soil Plutonium
Soil Americium
Soil Curium
Soil Berkelium
Soil Californium
Soil Einsteinium
Soil Fermium
Soil Mendelevium
Soil Nobelium
Soil Lawrencium
Soil Rutherfordium
Soil Dubnium
Soil Seaborgium
Soil Bohrium
Soil Hassium
Soil Meitnerium
Soil Darmstadtium
Soil Roentgenium
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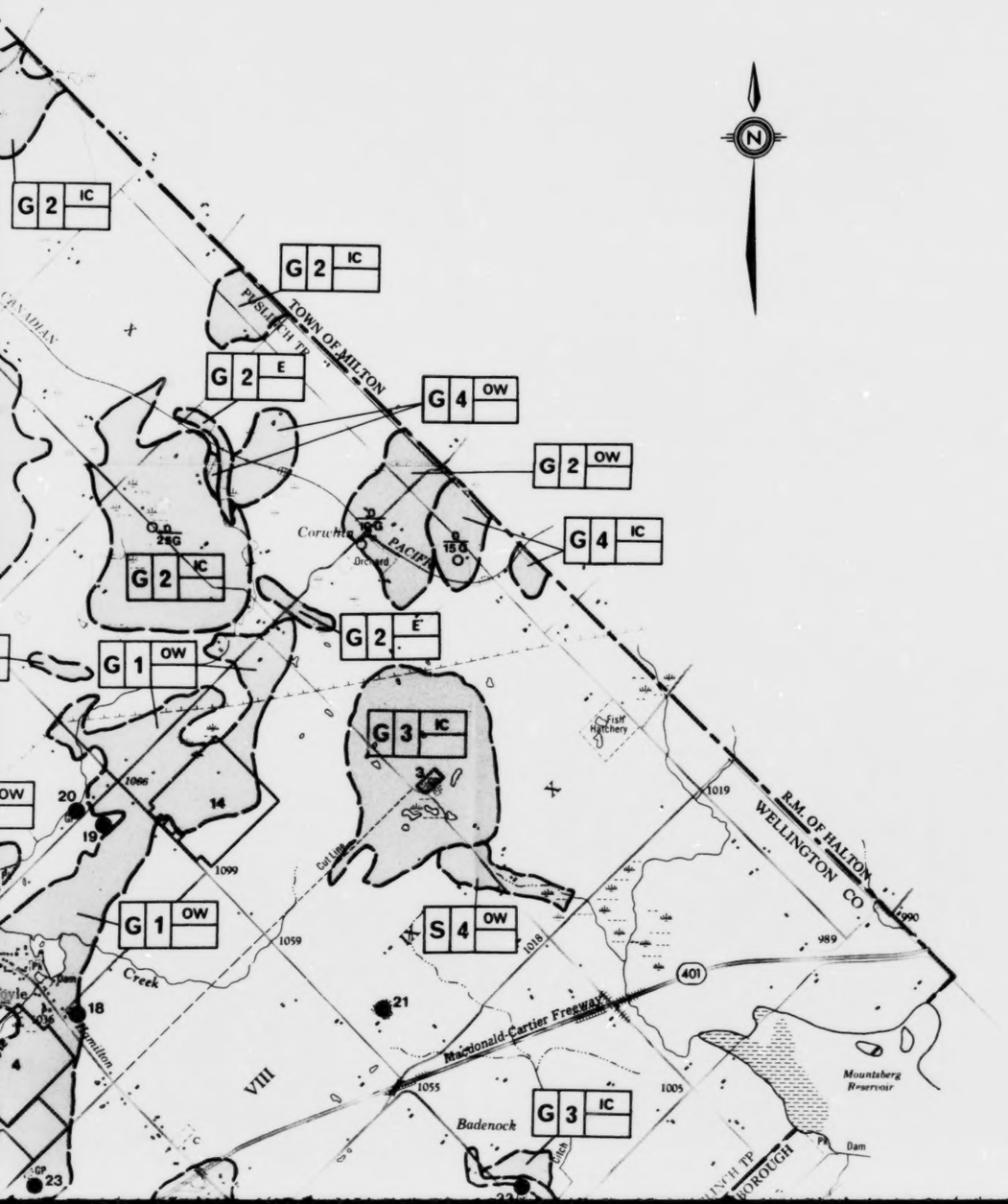
Soil Moscovium
Soil Livermorium
Soil Tennessine
Soil Oganesson



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Ministry of Natural Resources
Hon. Alan W. Pope, Minister
W.T. Foster, Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

PUSLINCH TOWNSHIP

WELLINGTON COUNTY

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale: 1:50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: 40 P/8
40 P/9

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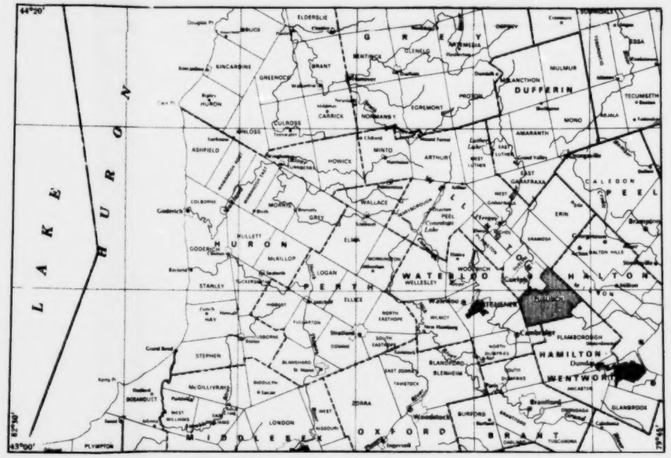


SYMBOLS

(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary. Shading indicates deposit area.
- S1 IC CLO — Deposit symbol: see below.
- 3 — Licenced property boundary; Property number: see Table 2.
- 4 — Unlicenced sand or gravel pit*; Property number: see Table 2 *Abandoned pit or wayside pit operating on demand under authority of a permit.
- 1/35G — Selected drilling location indicating thickness of overburden overlying reported thickness of granular materials (in feet).

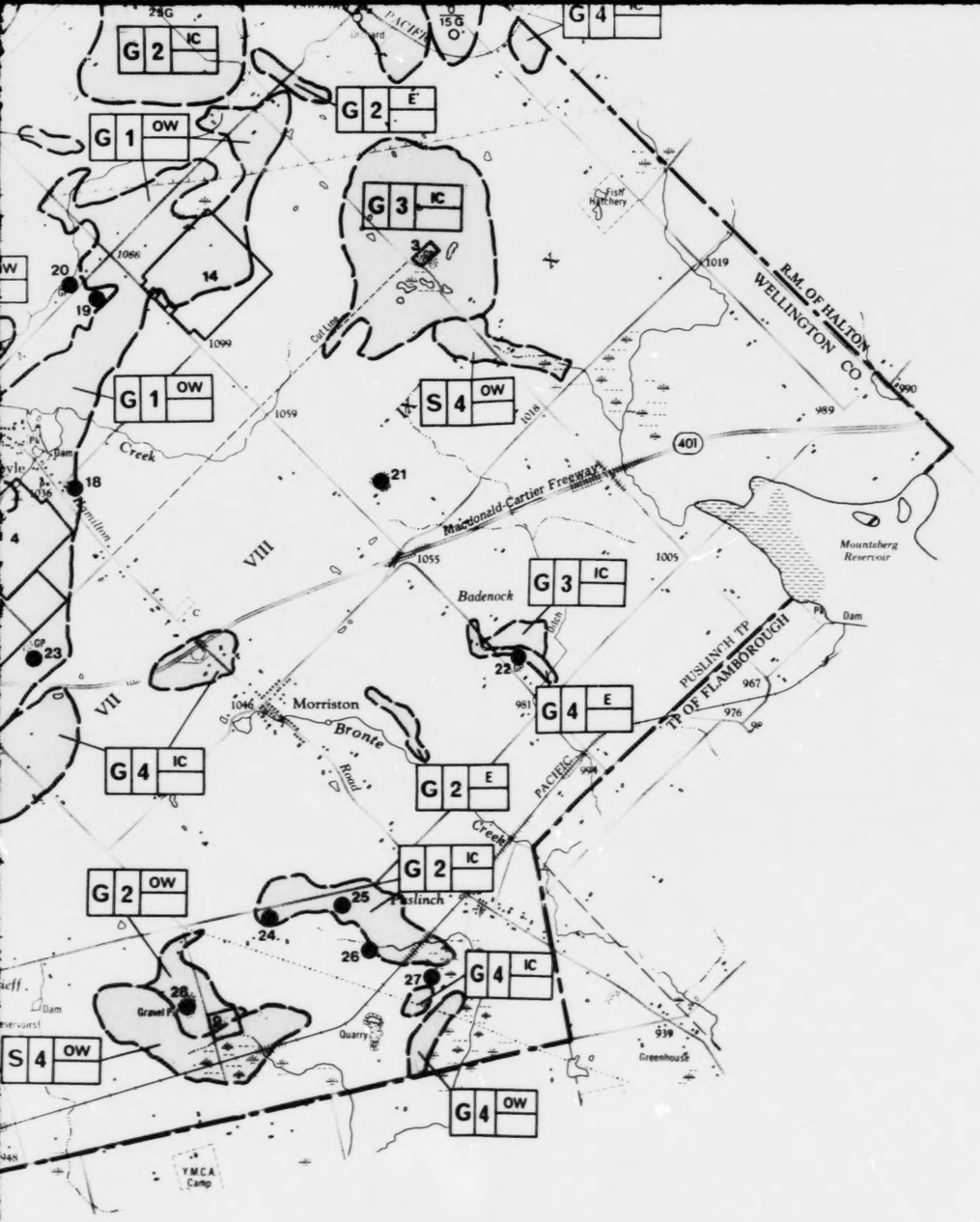
DEPOSIT SYMBOL (Continued)

Thickness Class

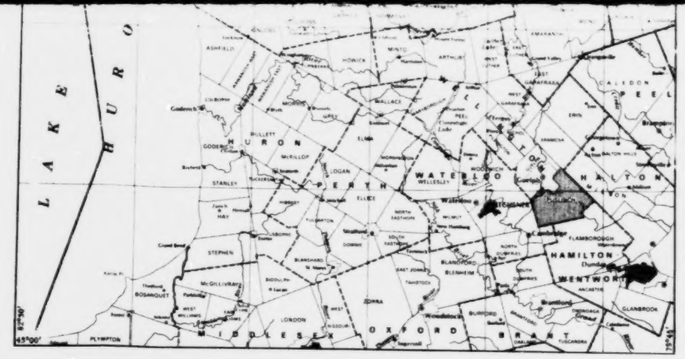
Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (>112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10	12,500-25,000

G 1 OW
S 4 OW
G 3 OW
G 2 OW
G 4 OW
G 4 IC
G 1 IC
G 1 OW
G 3 IC
S 4 OW
G 4 IC
G 1 IC
S 4 OW
G 4 OW
S 4 K
S 2 OW
S 4 IC
G 3 IC
G 4 IC
G 2 OW
G 1 IC
G 1 E
G 1 OW
G 4 IC
G 4 OW
G 1 IC
G 1 OW
G 4 OW
G 4 IC
G 4 E
S 4 OW
G 3 IC
G 3 OW
S 4 OW
S 4 OW
G 4 OW
S 4 LP
G 1 IC
G 4 OW
G 2 OW
G 4 IC
G 1 OW
G 2 IC
G 1 OW
G 3 IC
S 4 OW
G 4 E
G 2 E
G 2 IC
G 4 IC
G 4 OW

GUELPH TP
RIVER
Downeys
Speed
Eramosa
Dyke
Quarry
Trailer Park
Dam
Creek
Abertoyle
Hamilton
Greenhouses
Gravel Pits
Gravel Pit
Ditch
Irvine Creek
Historic Site
Gate
Service Centre
Little Lake
Trailer Park
Marina
Puslinch Lake
Rifle Range
Shoot Club
Golf Course
Gas pipeline (under)
Killean
Greenhouses
Crieff
Reservoirs
Gravel Pit
Quarry
Campsite
Poultry Farm
Y.M.C.A. Camp
Badenock
Ditch
Mountsberg Reservoir
Dam
Morriston
Bronte
Road
Creek
Puslinch
Fish Hatchery
Cut Line
Greenhouses
Macdonald-Cartier Freeway
401
PACIFIC
R.M. OF HALTON
WELLINGTON CO
PUSLINCH TP
TP OF FLAMBOROUGH
CITY OF CAMBRIDGE
R.M. OF WATERLOO CO
WELLINGTON CO
R.M. OF HAMILTON-WENTWORTH
TP OF NORTH DUMFRIES
CANADIAN
PUSLINCH TP
TP OF FLAMBOROUGH



PUSLINCH



SYMBOLS

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*Abandoned pit or wayside pit operating on demand under authority of a permit.

1/35G — Selected drilling location indicating thickness of overburden overlying reported thickness of granular materials (in feet). (Note: S - sand, G - gravel, T - till)

Municipal boundary.

DEPOSIT SYMBOL

Deposits are identified by gravel content, thickness class, deposit type and quality indicators. Gravel content is expressed as percentage of crushable material. Classes are based on potential aggregate tonnage per acre and are designated numerically. Type refers to geologic origin. Quality modifiers indicate variations in grain size distribution and lithology.

Gravel Content	Thickness Class	Geological Type
		Quality Indicators

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

DEPOSIT SYMBOL (Continued)

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (>112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500-25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12,500 (<28 000)

Geological Type

IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
ICT	Ice-Contact Terrace	LB	Lacustrine Beach
K	Kame	LP	Lacustrine Plain
E	Esker	LD	Lacustrine Delta
EM	End Moraine	AL	Older Alluvium
		WD	Windblown Forms

(see Appendix C for descriptions of Geological Types.)

Quality Indicators

	If blank, no known limitations present
C	Clay and/or silt (fines) present in objectionable quantities
L	Deleterious lithologies present
O	Oversize particles or fragments present in objectionable quantities

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
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This map is to accompany O.G.S. Aggregate Resources Inventory Paper 54.

GUELPH TP

ERAMOSA TP

ERAMOSA RIVER

TOWN OF MILTON

PUSLINCH TP

R.M. OF HALTON

WELLINGTON CO

GUELPH

Arkell

Scout

Gravel Pit 2

Orchard

Sewage

University of Guelph

Golf Course

Fur Farm

Radio 200

Gas Pipeline Under Ground

Guelph Line

CANADIAN PACIFIC

Corwhin Orchard

Fish Hatchery

Cut Line

Creek

Gravel Pits

Gravel Pit 17

Macdonald-Cartier Freeway

Badenock

Mountsberg Reservoir

Dam

Lime Plant

Dyke

Quarry

Tailings

Pond

BM 1009

GUELPH TP

RIVER

SPEED

I

II

III

IV

V

VI

VII

VIII

IX

1114

1107

1089

1111

1109

1103

1115

1062

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1031

1101

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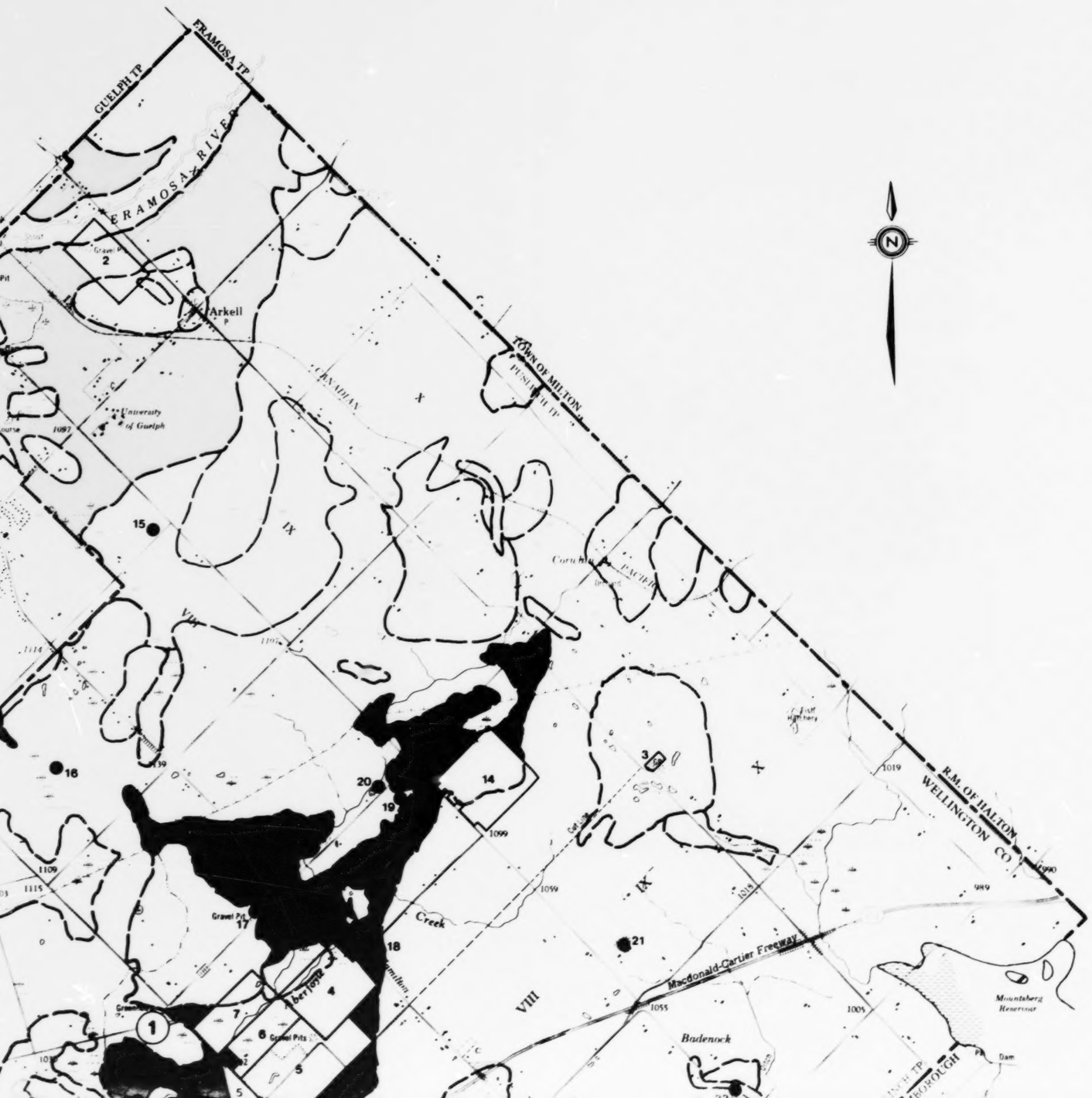

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Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

PUSLINCH TOWNSHIP

WELLINGTON COUNTY

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale: 1:50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: **40 P/8**
40 P/9

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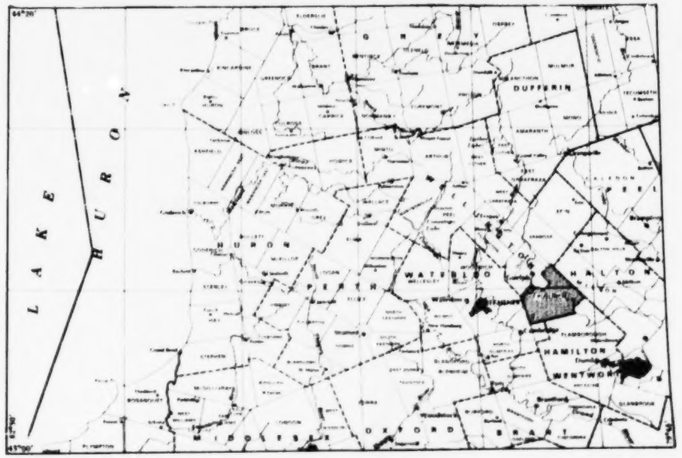

SYMBOLS
(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary.
- Selected sand and gravel resource area, Primary significance; Deposit number see Table 3.
- Selected sand and gravel resource area, Secondary significance.
- Selected sand and gravel resource area, Tertiary significance.
- Licenced property boundary, Property number see Table 2.
- Unlicenced sand or gravel pit*, Property number see Table 2.

GUELPH TP
RIVER
Guelph Line
Farm
Gravel Pit
Creek
Macdonald-Cartier Freeway
Fish Hatchery
R.M. OF HALTON
WELLINGTON CO
Mountsberg Reservoir
Badenock
Morriston
Bronte
Road
PUSLINCH TP
TP OF FLAMBOROUGH
PACIFIC
Puslinch
Crieff
Reservoirs
Quarry
Dam
Ditch
Campsite
YMCA Camp
Poultry Farm
Golf Course
Trailer Park
Marina
Puslinch Lake
Little Lake
Rifle Range
Skeet Club
Greenhouse
Gas pipeline (underground)
CANADIAN
WELLINGTON CO
R.M. OF HAMILTON-WENTWORTH
R.M. OF WATERLOO
TP OF NORTH DUMFRIES
CITY OF CAMBRIDGE
PUSLINCH TP
Killean
Galt
Lime Plant
Tailings
Quarry
Sawmill
Gravel Pits
Gravel Pit
Dam
Ditch
Creek
I
II
III
IV
V
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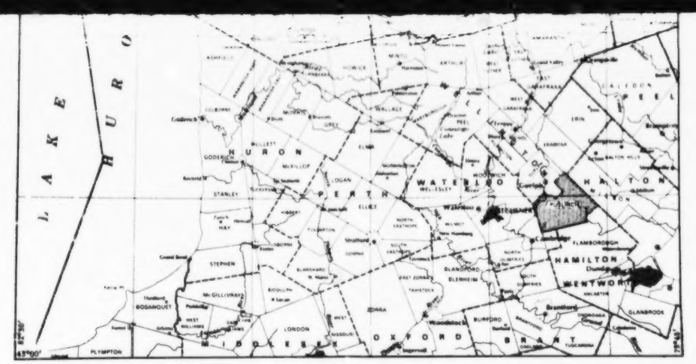
VII
VIII
IX
X



SYMBOLS

(Some symbols may not apply to this map)

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- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area, Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
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- Municipal boundary.

SOURCES OF INFORMATION

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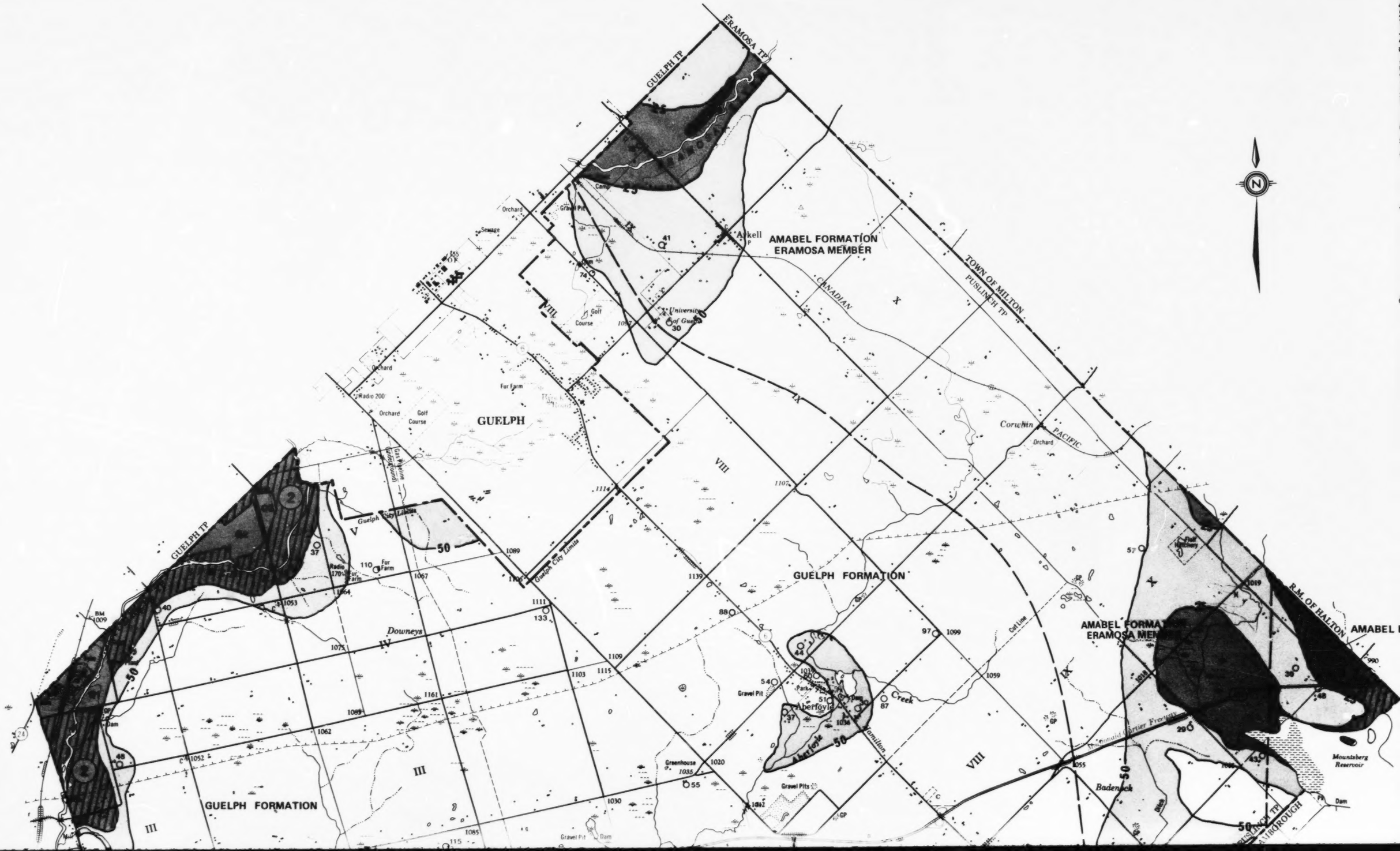
ERAMOSA TP
GUELPH TP
AMABEL FORMATION
ERAMOSA MEMBER
TOWN OF MILTON
PUSLINCH TP
CANADIAN
PACIFIC
GUELPH
GUELPH FORMATION
GUELPH TP
GUELPH FORMATION
AMABEL FORMATION
ERAMOSA MEMBER
R.M. OF HALTON
AMABEL
Downeys
Corwhin
Aberfoyle
Creek
Hamilton
Cut Line
Mountsberg Reservoir
Badenoch
Gravel Pit
Golf Course
Orchard
Fur Farm
Sewage
Radio 200
Radio 170
Greenhouse
Gravel Pits
Dam
Guelph City Limits
University of Guelph
Corwhin
Orchard
Aikell
Camp
Gravel Pit
Golf Course
Fur Farm
Orchard
Orchard
Golf Course
Gas Pipeline
Guelph City Limits
Guelph
Fur Farm
Radio 170
Fur Farm
Gravel Pit
Aberfoyle
Gravel Pits
Gravel Pit
Dam
Dam
Dam
Park
Park
Park
Pond
Pond
Pond

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W.T. Foster
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

PUSLINCH TOWNSHIP

WELLINGTON COUNTY

MAP 3
BEDROCK RESOURCES

Scale: 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: **40 P/8**
40 P/9

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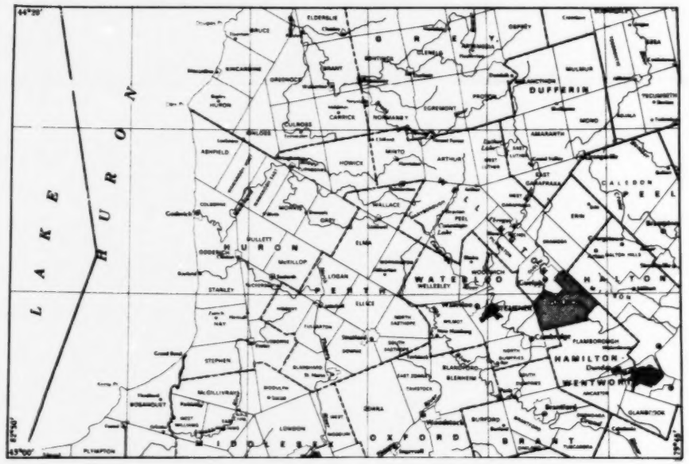


LEGEND

PALEOZOIC

SILURIAN

MIDDLE AND LOWER SILURIAN

GUELPH FORMATION
Dolostone

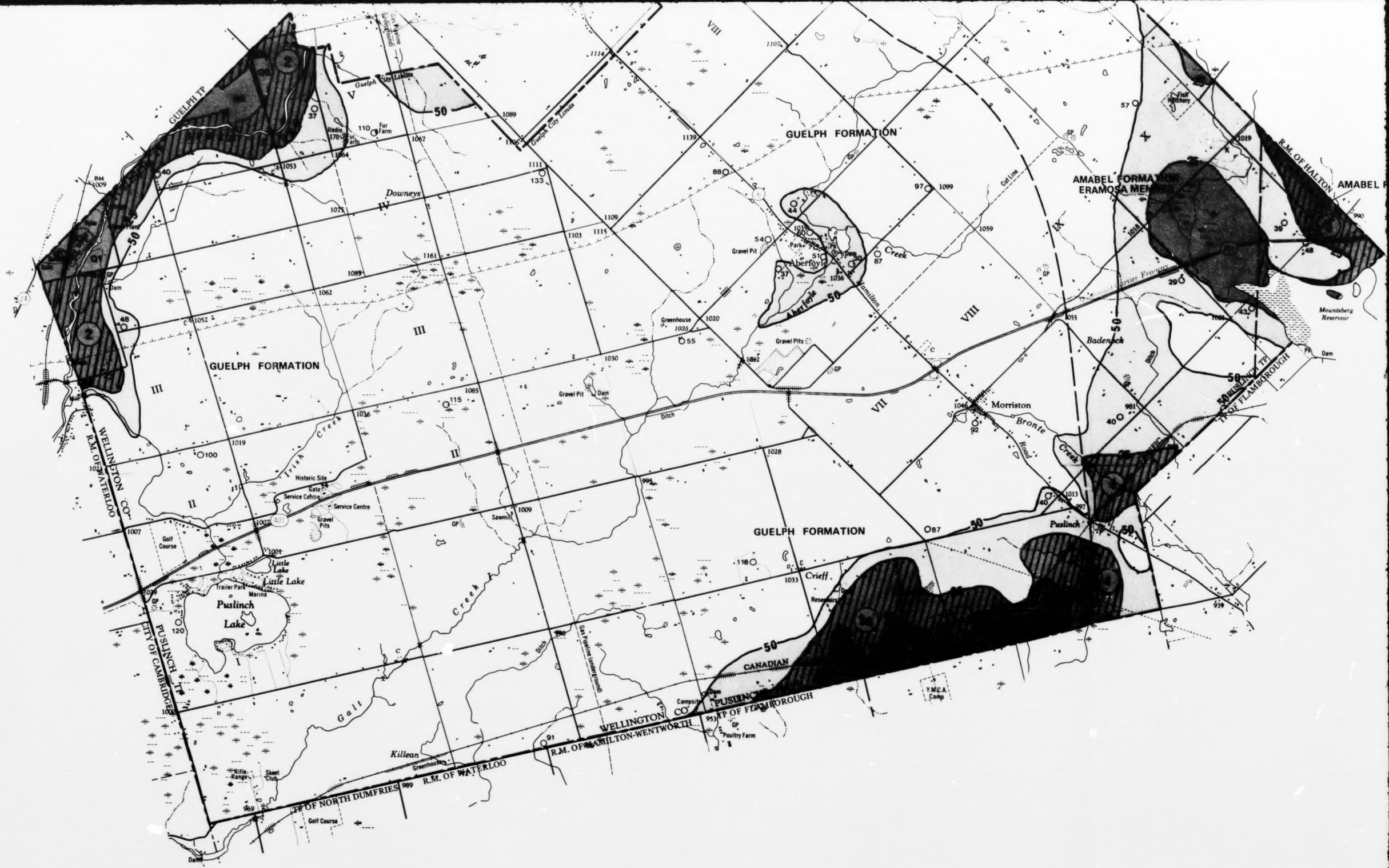
AMABEL FORMATION
Dolostone

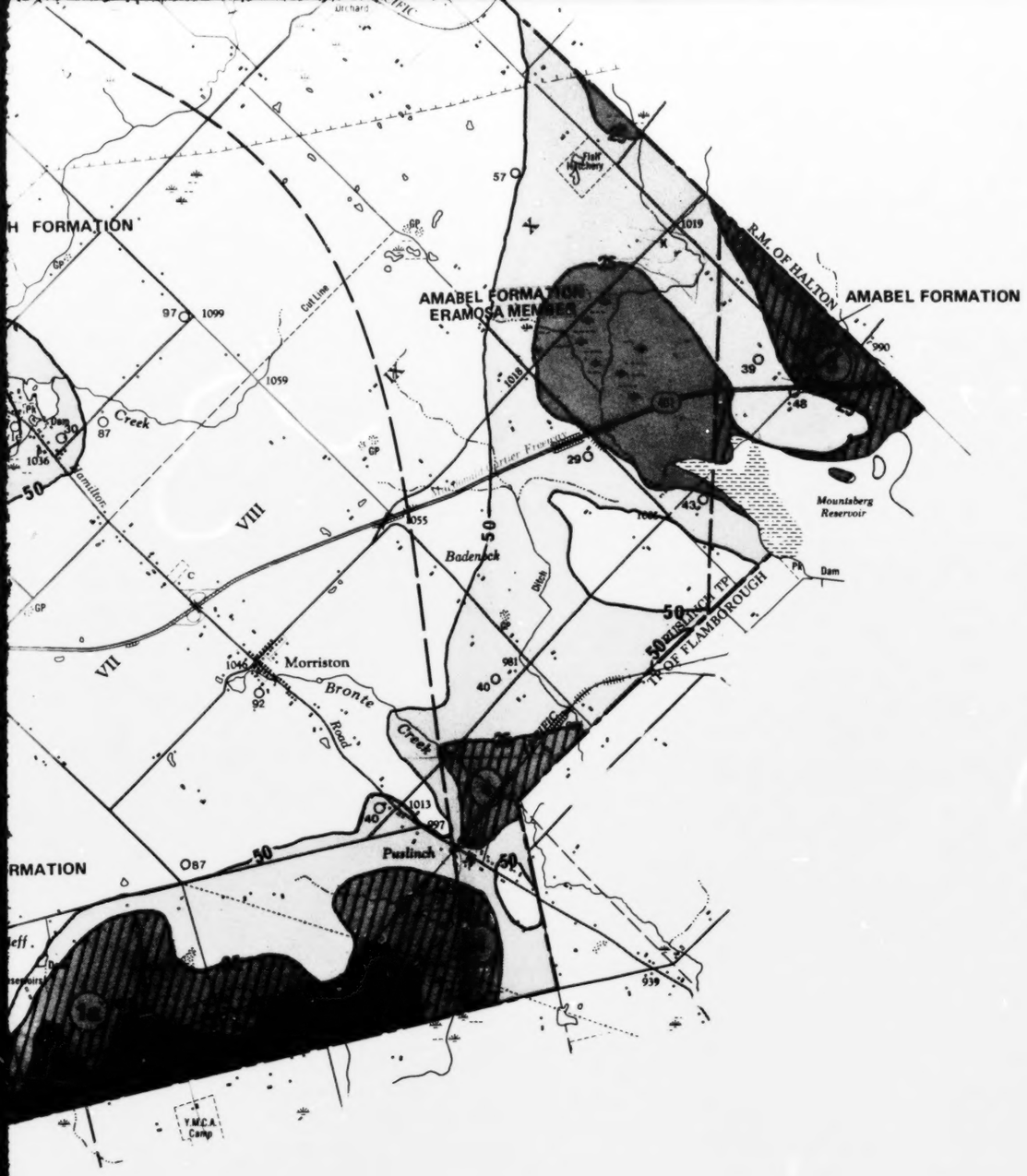
SYMBOLS
(Some symbols may not apply to this map)

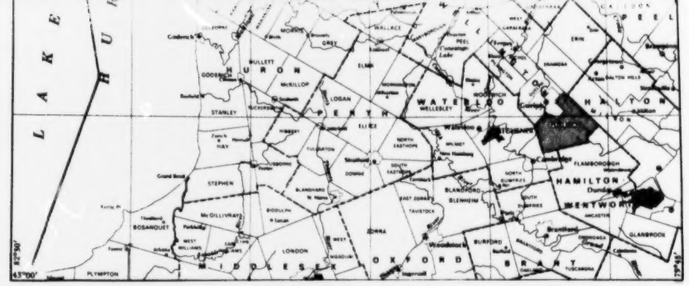
Formation thickness boundary (see text).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.


GUELPH TP
GUELPH FORMATION
AMABEL FORMATION
ERAMOSA MEMBER
R.M. OF HALTON
AMABEL F
Downeys
Guelph
Guelph City Limits
Gas Pipeline (Lindsay-Elmira)
Gravel Pit
Aberfoyle
Creek
Hamilton
Cut Line
Greenhouse
Gravel Pits
Badenoch
Mountsberg Reservoir
Morriston
Bronte Road
Creek
Fish Hatchery
Dam
Ditch
Irish Creek
Historic Site
Gate
Service Centre
Gravel Pits
Sawmill
Golf Course
Little Lake
Trailer Park
Marina
Puslinch Lake
PUSLINCH TP
CITY OF CAMBRIDGE
WELLINGTON CO
R.M. OF WATERLOO
Galt Creek
Killean
Greenhouses
Rifle Range
Skeet Club
TP OF NORTH DUMFRIES
Golf Course
Crieff
Reservoirs
CANADIAN
Campsite
Poultry Farm
Y.M.C.A. Camp
R.M. OF HAMILTON-WENTWORTH
TP OF FLAMBOROUGH
Puslinch
Fur Farm
Radio
Trans.
Tower
Sch.
Pit
Park
Plant
Campground
Fairgrounds
Cemetery
Quarry
Mine
Airport
Ski Hill
Ski Jump
Ski Tow
Lookout
Tourist Info.
Picnic Area
Camping
Boat Launch
Beach
Swimming Pool
Golf Course
Curling Rink
Arena
Hospital
Museum
Historic Site
Monument
Church
Cairn
Cemetery
Fire Tower
Fire Station
Police Station
Post Office
Library
Community Hall
Public Toilet
Telephone
Gas Station
Restaurant
Motel
Hotel
Tourist Home
Trailer Park
Marina
Boat Launch
Beach
Swimming Pool
Golf Course
Curling Rink
Arena
Hospital
Museum
Historic Site
Monument
Church
Cairn
Cemetery
Fire Tower
Fire Station
Police Station
Post Office
Library
Community Hall
Public Toilet
Telephone
Gas Station
Restaurant
Motel
Hotel
Tourist Home
Trailer Park
Marina





LEGEND

PALEOZOIC

SILURIAN

MIDDLE AND LOWER SILURIAN

GUELPH FORMATION
Dolostone

AMABEL FORMATION
Dolostone

SYMBOLS
(Some symbols may not apply to this map)

- Formation thickness boundary (see text).
- Geological boundary.
- 25 — Drift thickness contour line (25 foot (8 m) interval).
- × Isolated bedrock outcrop.
- Bedrock within 3 feet (1 m) of surface: see Table 4.
- Bedrock covered by 3 to 25 feet (1 m to 8 m) of overburden: see Table 4.
- Bedrock covered by 25 to 50 feet (8 m to 15 m) of overburden: see Table 4.
- (1) Selected bedrock resource area; Deposit number: see Table 6.
- Q3 Licenced quarry boundary; Property number: see Table 5.
- ●Q4 Unlicenced quarry*; Property number: see Table 5.
  *Abandoned quarry or wayside quarry operating on demand under authority of a permit.
- O39 Selected drilling location indicating reported depth to bedrock (in feet).
- Municipal boundary.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected drilling data from the Ontario Ministry of the Environment and the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: P.G. Telford, 1976, 1979.

Compilation and drafting by: Staff of the Aggregate Assessment Office.

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